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Ecosystem Services of the Terrestrial Isopod Armadillidium Vulgare: Implications for Cellulosic Litter Decomposition and Environmental Cleaning

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Abstract

This study aimed to evaluate the substrate-specific feeding behavior and decomposition efficiency of *Armadillidium vulgare* on diverse cellulose-based litters, with a focus on its potential role in sustainable organic waste management. Individuals of *A. vulgare* were collected from agricultural fields and gardens in the Amedi and Zaxo regions of Dohuk Governorate, Iraqi Kurdistan. In a controlled laboratory environment (25°C, 80% relative humidity), isopods were exposed to four types of cellulosic litters: banana peels, maize leaves, wood chips, and stiff paper. Five replicates of eleven individuals each were maintained per litter type for 14 days. Individual consumption measures, such as overall consumption, per capita consumption efficiency, and percentage of overall decomposition, were measured by the use of gravimetric measures. ANOVA was used to arrive at significant differences in substrates by conducting statistical analyses. The level of efficiency in consumption differed greatly among substrates ($P < 0.05$). Banana peels were the most efficiently consumed with the total of 44.11 g, 0.80 mg/capita efficiency, and the decomposition of 98.02%, it was then by maize leaves (40.69 g, 0.73 mg, 90.42 %), wood chips (37.14 g, 0.67 mg, 82.53 %) and the stiff paper (25.83 g, 0.46mg, 57.4 %). Variations in consumption patterns were influenced by substrate softness, nutrient composition, and structural complexity, rather than cellulose content alone. *A. vulgare* has distinct feed selectivity, which shows significant prospects as a bio-agent to be employed in decomposing soft and high-nutrient-content organic waste. The given findings emphasize its ecological importance in the nutrient cycles, soil fertility increase, and show the applicability of the species in the implementation of sustainable waste management and composting systems. The future research ought to explore the long-term dynamics of decomposition, the activity of digestive enzymes, and the interaction of the gut microbiome in order to maximize its application in the recycling of organic waste.

Keywords:

Armadillidium vulgare, cellulose decomposition, consumption efficiency, nutrient cycling, organic waste management, substrate preference, sustainable composting.

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Introduction

Armadillidium vulgare (Latreille, 1804) or the pill bug is a terrestrial isopod species, which is distributed globally, including in parts of the world like Australia, India, Iraq, Lebanon, Japan, South Africa, France, the United States of America, and Canada (Hu et al., 2025; Saeedi et al., 2022). They are adapted to moderately high temperatures and moisture, and the average conditions in which these organisms thrive include the humidity level of 60 to 80 % and the temperature of 19°C to 23°C (Boeraeve et al., 2021; Harris & Wright, 2021). Similar to other isopods, pill bugs are important decomposers, as they recycle nutrients by decomposing organic matter, including plant and fungal debris, and rotting wood, all of which play an important role in the cycling of nutrients and ecosystem operations (Spaldonova & Frouz, 2014; Kalaivnai, 2025). The most common organic substance on our planet is cellulose (Moraïs et al., 2024; Hamedi et al., 2025), which is the key ingredient in the environment, being one of the main constituents of plant cell membranes. Nevertheless, because it is too complex and many organisms lack the enzyme necessary to break down the cellulose, most organisms cannot break it down (Candia et al., 2025). The buildup of cellulose-rich wastes, such as plant wastes, paper, and farm wastes, is both a major environmental and aesthetic issue that results in pollution, degradation of habitat, and health (Mas'ud et al., 2025; Velliangiri, 2025).

Although the conventional ways of disposing of cellulose waste, including landfilling and burning, have been popular, these two processes usually cause a significant amount of environmental pollution and the release of greenhouse gases. Sustainable and efficient solutions to the cellulose waste management are urgently required (Salih et al., 2024). Despite terrestrial isopods such as *A. vulgare* being characterized by their capacity to decompose organic matter, limited studies have been done on their capacity to decompose cellulose-based products, which could provide a viable alternative to cellulose litter management.

Cellulosic waste in the ecosystems is becoming an issue of concern. Conventional methods of waste management are damaging to the environment, which requires an alternative. In this research, the conclusion is the investigation of the possibilities of *A. vulgare* as the biological agent that can be used to decompose all sorts of cellulosic litter, including maize leaves, wood chips, stiff paper, and banana peels, and the purpose of the study is to assess the use of this organism in cleaning the ecosystem. The research aims to learn the efficiency and preference of *A. vulgare* to eat various cellulosic sources and its possible role in the decrease in cellulosic waste.

The main aim of the study is to determine the capability of *A. vulgare* in consuming and decomposing the different kinds of cellulosic litter. In particular, the research will examine the rate of consumption of various types of cellulosic substances by *A. vulgare* and explore how effectively various materials are utilized. Also, the study aims to investigate how *A. vulgare* can be used to clean the environment, especially in the treatment of cellulosic waste (Coelho et al., 2022). This paper will examine the possibility of utilizing these isopods as a viable system approach to cellulose-based waste management in ecosystems by knowing their interaction with different cellulose substrates.

Hypothesis *A. vulgare* will exhibit different consumption rates and efficiencies of different cellulosic materials. The materials containing more carbohydrates and having greater palatability, like banana peels and maize leaves, should be consumed in larger quantities than less digestible materials like rigid paper and wood chips.

The experiment was done by gathering the *A. vulgare* from agricultural fields and gardens in the Amedi and Zaxo localities of Dohuk Governorate in Iraq. The isopods collected were reared in a controlled laboratory condition with the optimum humidity (80%) and temperature (25°C). A variety of cellulosic litters that included maize leaves, wood chips, rigid paper, and banana peels were used as food media. Measurement of the consumption rates was by the weight of the litters prior to and after the exposure to the isopods within a period of 14 days. Each type of litter was calculated, and the consumption efficiency per capita and the percentage of total consumption were given.

Key Contribution

The study offers a novel understanding of the potential of *A. vulgare* in controlling cellulosic waste, as it is sustainable and is a biological alternative to conventional waste disposal. The study shows that the pill bug can be used in cleaning and management of wastes in the environment by exemplifying its efficacy to consume various cellulosic materials. In addition, it aids in the comprehension of the ecological services performed by terrestrial isopods in the process of nutrient recycling and decomposition.

In the present research, *Armadillidium vulgare* (pill bug) is examined as a solution to the problem of plant waste, paper, and agricultural residues, which are harmful to the environment due to its ability to decompose cellulose. The ecological significance of its recycling in the nutrient recycling process is mentioned both in the introduction and its potential application in the control of cellulosic litter (banana peels, maize leaves, wood chips, hard paper) as a biological agent. The literature review highlights the previous studies on the importance of *A. vulgare* in litter degradation, nutrient cycling, and environmental cleaning, its substrate-specific feeding preferences and enzyme activities, and breaks in the research of waste decomposition. The materials and methods provide details on field collection in Dohuk, Iraq, laboratory rearing in controlled conditions, and consumption experiments on the Petri dishes in a period of 14 days, with data on total, per capita, and percentage consumption. Findings indicate that banana peels were fed on most effectively, followed by maize leaves, wood chips, and stiff paper. Substrate palatability, nutrient value, and structure are discussed as being connected to feeding efficiency to bring out ecological implications. The paper makes the conclusion that *A. vulgare* has the potential to be used as a sustainable cellulose waste management agent.

Literature Survey

One such insect is the terrestrial isopod *Armadillidium vulgare* (also referred to as the pill bug), which is a crucial component of the ecology of an ecosystem (specifically, in the decay of organic matter). The ecological functions of it cover a vast scope of services, such as decomposing litter, cycling of nutrients, and cleaning the environment (Wang et al., 2023; Chhabda et al., 2025). A number of studies have examined the role of *A. vulgare* in these processes, and it has brought insight into the significance of the plant in both natural and controlled environment settings (Lam et al., 2024).

Armadillidium vulgare has been noted to be a major decomposer of organic materials, especially in its capacity to degrade cellulosic materials such as litter (Mermillod-Blondin et al., 2025). The optimization of the various litter types consumed by the species, such as maize leaves, wood chips, stiff paper, and banana peels, underscores the disparity in the effectiveness of the species in the degradation of the different types of organic substances (Morales-Vega et al., 2025; Bredon et al., 2020). It has been experimentally verified that A. vulgare exhibits greater consumption efficiency and a preference towards more nutritious, softer food items such as banana peels and maize leaves, but is less efficient at consuming more rigorous and tougher food items such as wood chips and rigorous paper (Petrikovszki & Boros, 2025). A. vulgare was determined in more specific research performed by (Mondet et al., 2023) to be important in litter decay and stabilization of soil organic matter. Through this process, recycling of the essential nutrients back to the ecosystem is facilitated, and it is accessible to the growth of plants. The species hastens the decomposition of cellulose in the litter, which promotes soil health and fertility to a large extent.

Metabolic rates of *A. vulgare* are influenced by the type of litter it consumes. (Mermillod-Blondin et al., 2025) found that environmental organic carbon availability (such as the presence of decomposable cellulose) significantly influences the metabolic and consumption rates of *A. vulgare* (Fontes-Candia et al., 2025; Kristensen & Einarsson, 2022). These findings are not out of place with other authors who demonstrate that the feeding on simple organic waste like banana peels is more prominent than the more complex ones like rigid paper and wood chips (Salman & Mahdi Alsalman, 2025). Also, experiments on the digestive systems of terrestrial isopods show that these animals have also developed specialized adaptations to digest cellulose, which is a primary constituent of the litter of plants. This goes even further to emphasize their significance in the decomposition of litter, especially in areas that contain high amounts of cellulose-based organic matter.

The decomposition of organic matter by *A. vulgare* is known to be of paramount importance in the nutrient cycle, in particular, in the breaking down of cellulose to release important nutrients like nitrogen, phosphorus, and potassium into the soil. It makes the soil fertile by enriching it, which is beneficial to the growth of plants (Salman & Mahdi Alsalman, 2025). Using cellulose material, A. vulgare is able to work on the decomposition of complex organic compounds, as the structures are more easily made available to plants. This recycling plays a critical role in balancing ecosystems, and the fertility of soil is preserved throughout the decades (Oliveira et al., 2021). *A. vulgare* also offers one of the most notable ecosystem services, and that is environmental cleaning (Al-Rashid & Greaves, 2025). Through eating the rotting plant materials and detritus, *A. vulgare* assists in the elimination of waste in the land-based ecosystems. This helps to decompose the organic waste and decreases littering that would build up, and also helps to promote the cleanliness of the forest floors and other natural habitats. In addition, being an efficient decomposer, *A. vulgare* contributes to the reduction of the accumulation of harmful organic compounds indirectly, which helps to restore the ecological balance (Hornung, 2024).

The introduction of *A. vulgare* into the biosphere can also lead to an increase in biodiversity by providing a good environment for plant growth. The *A. vulgare* process of decomposing results in nutrients returning to the soil and, therefore, supports various plant species (Karasawa et al., 2024). This, in its turn, sustains the existence of different organisms that rely on plants as a source of food and shelter. In addition, degradation of organic matter also affects the microbial populations in the soil, making the soil ecosystem healthier and more biodiverse (Liao et al., 2023). The uses of *A. vulgare* are not merely useful in the natural ecosystems, but also may be utilized in environmental management. An example is A. vulgare that may be utilized in waste management plans, especially in the treatment of plant-based waste materials in agricultural or forestry activities. Since it is capable of effectively degrading the cellulose, *A. vulgare* might aid in the minimization of the organic waste in a regulated context, e.g., composting plants, which is a part of the overall waste recycling initiative (Mas'ud et al., 2025).

Isopod *A. vulgare* has important roles in the processes of the ecosystem, especially in litter cellulose decomposition and nutrient recycling. It has the capacity to break down organic materials effectively, which leads to the fertility of the soil, environmental purity, and the overall well-being of the ecosystem. The species *A. vulgare* is a dominant one in the terrestrial ecosystem, as it is found to contribute to waste reduction, nutrient cycling, and conserving biodiversity, as indicated in the reviewed studies. The other research should be conducted in the future to address the extended ecological significance of *A. vulgare* and its possible use in the environmental management plan.

Materials and Methods

Sample Collection

The sample of *Armadillidium vulgare* (*A. vulgare*) was picked in farms and gardens in the Amedi and Zaxo regions of Dohuk Governorate, Iraqi Kurdistan (Figures 1 and 2). The plots were done in the early morning and evening to allow minimum disturbance to the natural habitat, and it was done by the use of a hand trowel and hand. This type of sampling was sufficient to sample healthy, active persons to undertake the next experimental process.

Figure 1. Aerial view of amedi, dohuk governorate, iraqi kurdistan, showcasing the mountainous terrain and surrounding landscape

Source: https://www.kurdistan24.net/index.php/ar/story/832754

Figure 2. Dorsal view of armadillidium vulgare (latreille, 1804), showing its external morphology image captured at 1200x magnification

The habitat where *A. The* growing of A. vulgare was also given serious consideration when collecting *A. vulgare*. The isopods are usually located in wet and sheltered zones like below stones, logs, and litter leaves in forests, fields, and gardens. Figure 3 shows the natural environment of *A. vulgare*, where such creatures are found in their natural habitat.

Figure 3. Natural habitat of *Armadillidium vulgare* (Latreille, 1804), showing a group of individuals among organic debris and vegetation in the wild

Selection of Cellulosic Litters

The litters of the cellulose were harvested in different settings in order to have a wide selection of substrates to use in the experiment. The chosen materials were the leaves of maize, which are found in farms, wood chips, which are found in the carpentry shops in the market, and the piece of paper that becomes stiff, which is found in the market, and finally the banana peel, which is found in the household garbage. These litters were selected to reflect typical types of cellulosic waste that occur in agricultural, commercial, and domestic systems, thus allowing a full evaluation of how *Armadillidium vulgare* can consume and decompose a variety of cellulose-based substances.

Breeding of A. vulgare

This was done by raising the *A. vulgare* individuals that were collected under a controlled laboratory setting. Rearing containers were transparent 20 L plastic boxes. The boxes were loaded with moist soil and fed with mulberry leaves (Grosset & Faberi, 2018) to get the necessary nutrition. The temperature and relative humidity in the laboratory were kept at 25°C ± 1°C and 80% ± 5% to provide the best environmental conditions for *A. vulgare*, as advised by the past research (Hornung, 2023). It was lined with a fine tulle cloth (diameter of the holes: 2 mm) that allowed the containers to be easily ventilated and at the same time the isopods not to escape. The breeding procedure was to be used to produce a population of *A. vulgare* of the same age to undergo the consumption tests.

Consumption Test of A. vulgare on Cellulosic Litters

In the case of the consumption tests, 16 cm diameter Petri dishes were used, whereby filter paper was laid at the bottom of every dish to facilitate equal distribution of moisture. The four types of cellulosic litter used in the dishes had 9 g each and were well washed, dried, and broken into small pieces to make their size uniform and easy to be consumed by *A. vulgare*. The litters were then fed to *A. vulgare* individuals, each of about seven months old. A total of twelve respondents were assigned to every dish, with five duplicate dishes per type of litter, in order to guarantee the accuracy of findings.

The experimental conditions were held under 25°C ± 1°C temperature and 80% relative humidity ± 5%. The tulle cloth was used to cover the Petri dishes to keep them wet and allow air to get in, keeping the isopods at their best. The experimental time was determined as 14 days to give enough time to the isopods to feed and degrade the litter. The Petri dishes were gathered, and care was given at the end of the 14 days, and the balance of the weight of the litter was registered using a delicate balance.

Calculation of Consumption

The consumption of each type of cellulosic litter was calculated using the following formulas:

Consumed weight:

$$W_{\text{consumed}} = W_{\text{initial}} - W_{\text{remaining}} \tag{1}$$

Consumption efficiency per capita:

$$E_{\text{per capita}} = \frac{W_{\text{consumed}}}{N} \tag{2}$$

Percentage of total consumption:

$$P_{total} = \frac{W_{consumed}}{W_{initial}} \times 100 \quad (3)$$

The consumption rate for each type of cellulosic litter was calculated using three main equations. Equation 1, the consumed weight ($W_{consumed}$) was determined by subtracting the remaining weight of the litter ($W_{remaining}$) from the initial weight ($W_{initial}$). In equation 2, the consumption efficiency per capita ($E_{per\ capita}$) was calculated by dividing the total consumed weight ($W_{consumed}$) by the number of individuals (N) in each replicate. In equation 3, the percentage of total consumption (P_{total}) was computed by dividing the consumed weight ($W_{consumed}$) by the initial weight of the litter ($W_{initial}$) and multiplying by 100. These formulas allow for the evaluation of the consumption rates and efficiency of *A. vulgare* in decomposing the cellulosic litter.

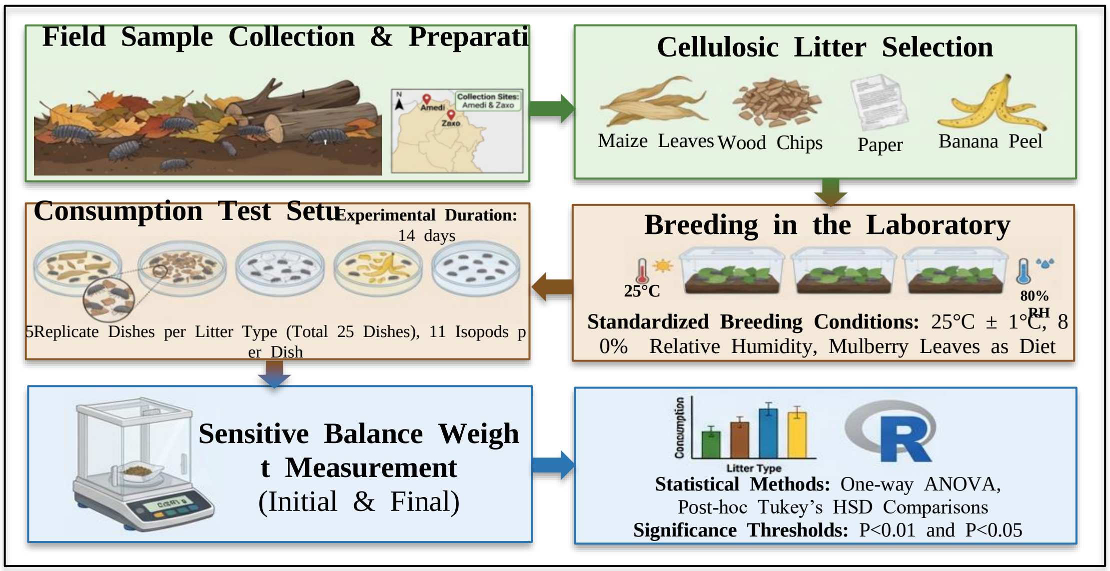

Figure 4. Schematic workflow of sample collection, breeding, and consumption testing of Armadillidium vulgare on cellulosic litters

Statistical Analysis

Analysis of variance (ANOVA) was used to analyses the significance of the difference in rates of consumption and litter quality among the various treatments. Data are presented as means ± standard error (SE). Where significant differences were detected, post-hoc comparisons were performed to identify pairwise differences between treatments. The P-value of significance of within-group comparison was set at $P < 0.01$, and between-group comparison at $P < 0.05$. R software (version 4.3.1) was used to conduct all the statistical analyses.

Results

To determine the ability of *Armadillidium vulgare* (*A. vulgare*) to degrade cellulose-based substances, the consumption efficiency of this insect was measured on various kinds of cellulosic litter. Four types of litter: maize leaves, wood chips, stiff paper, and banana peels were under controlled laboratory conditions. The findings are given in terms of the total consumption, the efficiency of the consumption per head, and the percentage of the total consumption. Statistical tests showed a significant difference in statistics among litter types and between litter types, and these are summarized in subsequent sections and plotted through tables and figures.

Calculation of Consumption Metrics

To quantify the consumption efficiency of *A. vulgare*, standard gravimetric and per capita metrics were calculated as follows:

Total Consumption (TC)

$$TC = W_i - W_r \quad (4)$$

In equation (4), W_i is the initial litter weight (g), and W_r is the remaining litter weight after the experimental period.

Per Capita Consumption Efficiency (PCCE)

$$PCCE(mg) = \frac{TC \times 1000}{N} \quad (5)$$

TC, the total consumption (g), and N are the total number of individuals in the equation (5).

Percentage of Total Consumption (PTC)

$$PTC(\%) = \left(\frac{TC}{W_i}\right) \times 100 \quad (6)$$

The TC and Wi denote the total consumption (g) and the initial litter weight (g), respectively, in equation (6). These parameters allowed the comparison of the efficacy of consumption of different types of cellulosic litter.

Maize Leaves Consumption

The overall consumption of the maize leaves by *A. vulgare* was significant during the 14 days of experimentation, with the cumulative consumption standing at 40.69 g. The range of individual replicate consumption was close, with 8.13 g and 8.16 g, with a resultant weight of 4.31 g. The statistical analysis showed there was a great variation between replicates within this treatment (P < 0.01), which means that there are quantifiable differences in feeding activity despite the general consistency.

Table 1. Efficiency consumption of individuals A. vulgar for maize leaves litter

Sample replicates	**Number of individuals**	**Weight litters before consumption/gm**	**Consumed weight/gm**	**Remaining weight/gm**
1	11	9	8.13	0.87
2	11	9	8.14	0.86
3	11	9	8.16	0.84
4	11	9	8.13	0.87
5	11	9	8.13	0.87
The total	55	45	40.69	4.31

* Correlations within the group were significantly (P < 0.01).

As shown in Table 1, maize leaves were efficiently consumed, accounting for over 90% of the initial litter weight. This finding shows that maize leaves are a very suitable and digestible food *for A. vulgare*.

Wood Chips Consumption

The consumption rate of wood chips was a bit lower than that of maize leaves, since it had consumed 37.14 g, and a weight of 7.86 g was left. The values of consumption, when bought individually, were 7.41 g to 7.45 g. Even though the difference between replicates was small, the statistical analysis revealed significant differences within groups ($P < 0.01$).

Table 2. Efficiency consumption of individuals A. vulgar for wood chip litter

Sample replicates	Number of individuals	Weight litters before consumption /gm	Consumed weight/gm	Remaining weight/gm
1	11	9	7.44	1.56
2	11	9	7.41	1.59
3	11	9	7.42	1.58
4	11	9	7.42	1.58
5	11	9	7.45	1.55
The total	55	45	37.14	7.86

* Correlations within the group were significantly ($P < 0.01$).

The results in Table 2 indicate that wood chips were moderately consumed by *A. vulgare*. Nevertheless, they consumed much less of them than maize leaves do, which indicates that the rigidity of a wood chip structure decreases its palatability and efficiency in decomposition.

Stiff Paper Consumption

The lowest consumption was observed in stiff paper of the experimented substrates. Total consumptions amounted to 25.83 g with replicate values of 5.14 g to 5.19 g and a fairly high remaining weight of 19.17g. It was observed that there was significant variation between replicates ($P < 0.01$), although the overall low level of consumption was observed.

Table 3. Efficiency consumption of individuals A. vulgar for stiff paper litter

Sample replicates	Number of individuals	Weight litters before consumption /gm	Consumed weight/gm	Remaining weight/gm
1	11	9	5.14	3.86
2	11	9	5.17	3.83
3	11	9	5.19	3.81
4	11	9	5.17	3.83
5	11	9	5.16	3.84
The total	50	45	25.83	19.17

* Correlations within the group were significantly ($P < 0.01$).

Solid paper was fed inefficiently compared to any other litter, as seen in Table 3. This observation indicates that even though stiff paper is cellulosic, its structural rigidity and reduced nutrient supply make it less desirable as a source of food to *A. vulgare*.

Banana Peels Consumption

Banana peels recorded the highest consumption rate as compared to all other substrates, and the total consumption was 44.11 g, with the least remaining weight at 0.89 g. The consumption by individuals varied between 8.81 g and 8.84 g. There was a large amount of within-group variation ($P < 0.01$), but there was a generally high level of consumption.

Table 4. Efficiency consumption of individuals A.vulgare for banana peels litter

Sample replicates	Number of individuals	Weight litters before consumption /gm	Consumed weight/gm	Remaining weight/gm
1	11	9	8.84	0.16
2	11	9	8.81	0.19
3	11	9	8.81	0.19
4	11	9	8.82	0.18
5	11	9	8.83	0.17
The total	55	45	44.11	0.89

* Correlations within the group were significantly (P < 0.01).

Table 4 demonstrates that banana peels were almost completely consumed, indicating a strong preference and high decomposition efficiency by *A. vulgare* compared to other cellulosic litters.

Inter-litter Variation in Consumption Patterns

The consolidated violation plots offer a graphical difference between the variability of consumption of the four litter types (stiff paper, banana peels, wood chips, and maize leaves).

Figure 5 shows the violin plot of stiff paper with a thin distribution between a low median, which also validates the little use of it. Conversely, banana peels depict maximum consumption with a small distribution, meaning that there is a high consumption rate in all replicates. The statistical comparisons determined that banana peels were eaten much more than all other forms of litter (P < 0.05).

The consumption of wood chips was intermediate and showed a wider distribution compared to maize leaves. The variability was moderate, and the preference was moderate as well. Maize leaves were found to be more likely to be consumed as compared to wood chips and stiff paper, and this shows that there is a relatively high degree of preference, although it is lower than that of banana peels.

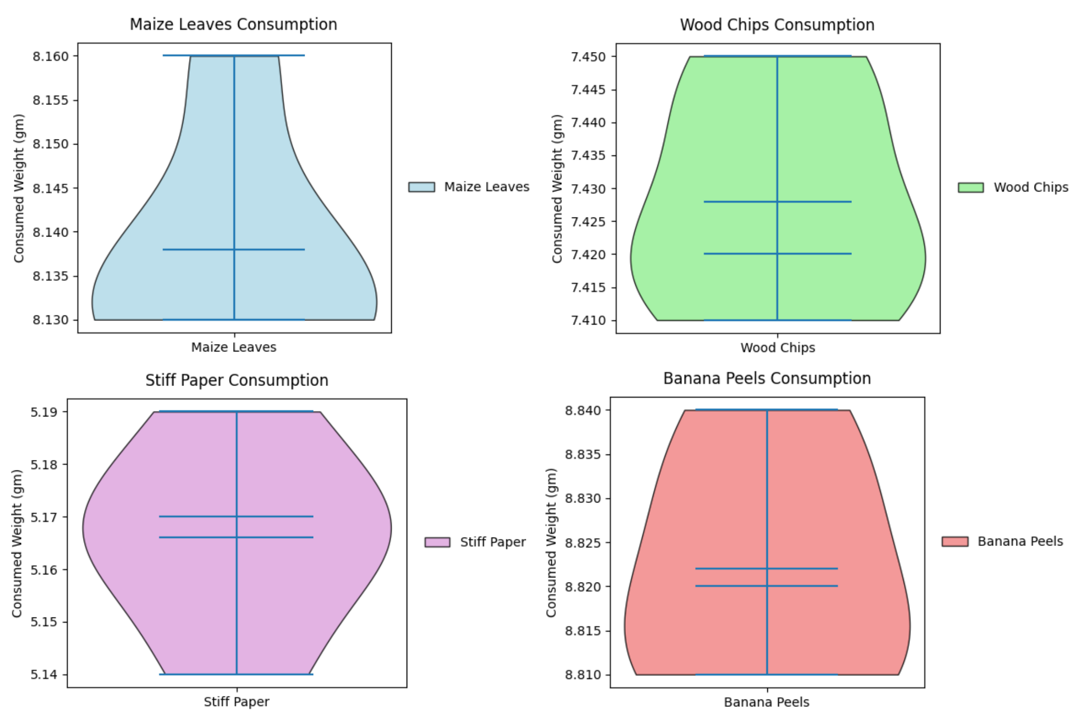

Figure 5. Consumption efficiency across different litter types by A. vulgare

Consumption Efficiency and Total Consumption

Per capita consumption efficiency and percentage of total consumption further supported the observed substrate preferences (Table 5).

Table 5. Efficiency consumption per capita A. vulgare and percentage of total consumption for cellulosic litters

Type of cellulosic litter	Total number of individuals	Total litter's weight before consumption	Total consumption/gm	Consumption efficiency per capita/mg	Percentage of total consumption
Maize leaves	55	45	40.69	0.73	90.42%
Wood chips	55	45	37.14	0.67	82.53%
Stiff paper	55	45	25.83	0.46	57.4%
Banana Peels	55	45	44.11	0.80	98.02%

* Correlations between groups were significantly (P < 0.05).

Banana peels exhibited the highest per capita consumption efficiency (0.80 mg per individual) and the highest percentage of total consumption (98.02%). This was followed by maize leaves (0.73 mg; 90.42%), wood chips (0.67 mg; 82.53%), and stiff paper (0.46 mg; 57.4%). The differences in litter types were statistically significant (P < 0.05).

Figure 6 visually summarizes these results, highlighting the markedly higher consumption of banana peels compared to the other substrates.

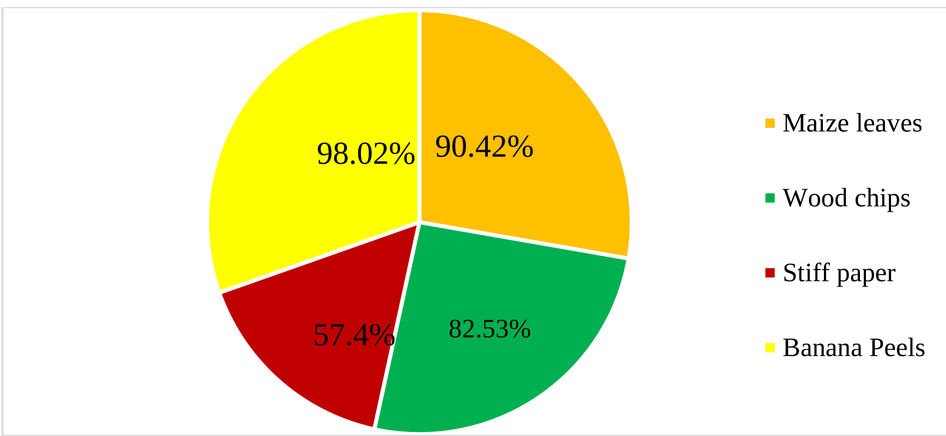

Figure 6. Percentage of total consumption of cellulosic litter by individuals A.vulgare

Altogether, A. vulgare showed evident statistically significant variations in the consumption efficiency of the tested cellulosic litters. The order of preference of the substrates was as follows: banana peels > maize leaves > wood chips > stiff paper. These results indicate that the consumption of the softer, nutrient-enriched, and easier-degradable substrates is more efficient compared to the rigid or fibrous ones. The findings highlight the substrate-selective feeding of the *A. vulgare* and its possible contribution to the degradation of organic waste, especially soft materials of plant origin.

Discussion

Terrestrial isopods, like *Armadillidium vulgare*, are also important litter decomposers and contribute to the recycling of nutrients, including rotting wood, decaying leaves and fruits, and other cellulose-containing materials (Karrasaw et al., 2024). As shown in the present study, A. vulgarre showed substrate-selective feeding habits and consumption efficiencies whenever subjected to various kinds of cellulosic litter, indicating the nutritional quality as well as the structural makeup of the food sources. *A. vulgare* uses a wide range of cellulose-based materials, which are closely related to the digestive physiology. The Armadillidiidae have a robust hepatopancreatic (midgut gland) that contains a high concentration of intracellular digestive enzymes to degrade cellulose, hemicellulose, and other complex carbohydrates (Depeux et al., 2020). This enzymatic ability allows the efficient digestion of vegetal organic contents and is the reason why the total consumption rates were high in all the tested substrates under this study.

These findings make it clear that banana peels were the most successfully consumed food material of the *A. vulgare* in that the total consumption (44.11 g), the capita consumption efficiency (0.80 mg), and the percentage of total consumption (98.02%) were the highest. The preference for this substrate is also well supported by the fact that the variation is always small between the replicates, as seen in Figure 4. This consumption rate is due to the positive nutritional value of the banana peels that were analyzed to have high carbohydrates (22.86 g), moderate protein (1.10 g), lipids (0.35 mg), and calcium (5 mg) as demonstrated by GC-MS analysis. Besides this, banana peels are also known to have vitamins, crucial minerals, and soluble sugars, which can be more palatable, making them especially desirable to the terrestrial isopods (Oliveira et al., 2021; Morales-Vega et al., 2025; Ganault et al., 2022; Blondin et al., 2025). Their softer texture and reduced structural resistance were also likely to make them easy to consume rapidly.

Maize leaves were the second highest in consumption efficiency, with a total consumption of 40.69 g, a per capita consumption efficiency of 0.73mg, and a high proportion of the overall consumption (90.42%). The violin plot indicates a fairly broad distribution with a moderately high median, which implies good palatability as well as some variability between the replicates. The high concentrations of carbohydrates (20 g), protein (3.3 g), lipids (1.3 g), and calcium (6mg) were the reasons that maize leaves could be utilized well by *A. vulgare*. These data indicate that maize leaves can be used as a balanced nutritional source sustaining feeding, but their fibrous texture can be slightly disadvantageous to consumption relative to banana peels.

Wood chips were fed on in an intermediate level, and they were third in the list of substrates tested. The total consumption was 37.14 g, with a per capita efficiency of 0.67 mg and 82.53% total consumption. Wood chips are a valuable source of cellulose, although they have fairly high protein (20 g) and calcium (4 g) and a heterogeneous plant origin, which probably lowered their digestibility due to a higher lignin content. The wider spread of the violin plot is a sign of medium preference with more variability to replicates, which means that although *A. vulgare* can substantially process woody material, it is not as effective as softer plant litters. Stiff paper exhibited the lowest consumption efficiency, with a total consumption of 25.83 g, a per capita efficiency of 0.46 mg, and only 57.4% of total consumption. Despite being composed largely of cellulose nanofibers (approximately 40–50% of biomass), stiff paper is structurally rigid and chemically processed, which may reduce enzyme accessibility and palatability. Its content of calcium was also quite good (40 g), but the reduced carbohydrate content (9.60 g) and small size of the fibre structure would have limited feeding efficiency. The distribution of the violin plot is also narrow and low-centered, which confirms the conclusion that stiff paper is not the most desirable substrate of *A. vulgare*.

The composition of all tested litters was that of cellulose, proving that cellulose availability alone is not a predictor of feeding preference. Rather, the decelerating effects on the consumption patterns of substrate softness, the nutrient content, chemical composition, and structural complexity have critical roles. The ranking of substrates, banana peels > maize leaves > wood chips > stiff paper, is clear evidence of the importance of food quality and digestibility in the control of isopod feeding behavior. The identified consumption levels are aligned with the earlier results, which indicated that *A. vulgare* and other terrestrial isopods have cellulolytic enzymes and symbiotic microorganism structures that promote cellulolytic degradation (Horváthova et al., 2019; Bredon et al., 2020; Liao et al., 2023). The rate at which this process occurs, however, differs with the nature of the substrate, with soft and nutrient-rich organic matter decomposing faster than the tougher, lignified, or processed material.

Conclusion

This research offers quantitative data to demonstrate that statistically significant differences in consumption efficiency are substrate-specific to *A. vulgare* when exposed to a variety of cellulose-based litters. Analysis of variance showed that the total consumption, per capita consumption efficiency, and the percentage of litter decomposition among substrates differed significantly ($P < 0.05$) over the 14-day experiment, and thereby confirmed the fact that feeding performance is not only strongly affected by the cellulose content of substrates but also by their nature. Banana peels showed the highest consumption efficiency (44.11 g total consumption, 0.80 mg per capita, and 98.02% decomposition), followed by maize leaves (40.69 g, 0.73 mg, and 90.42%), wood chips (37.14 g, 0.67 mg, and 82.53%), and stiff paper (25.83 g, 0.46 mg, and 57.4%). The statistically validated consumption hierarchy banana peels > maize leaves > wood chips > stiff paper underscores the imperative nature of substrate softness, nutrients, and complexity structure in the control of decomposition efficiency. The wide statistical differentiation of litter types is an emphasis on the validity of A. vulgare as a biological indicator of the quality and degradability of substrates. The implications that these findings have on sustainable waste management are that terrestrial isopods are highly efficient in using soft and nutrient-rich organic materials, like fruit wastes and vegetal agricultural by-products. The biodegradation rate and the accumulation of biodegradable waste could be increased by the incorporation of such detritivores in the organic waste management and composting systems, and could encourage the environmentally sustainable recycling of nutrients. The long-term consumption trial, seasonal fluctuation, and multigenerational experiment are some of the areas of future research that should be given importance to determine the durability of such feeding habits over time. Furthermore, by incorporating the analysis of enzyme activities, the characterization of the gut microbiome, and the lignocellulosic breakdown profiles, it will be possible to clarify the physiological and microbial processes in the selection of substrates. From an applied perspective, scaling experimental systems to pilot composting units and evaluating isopod-mediated decomposition under field conditions will be essential steps toward translating these statistically validated findings into practical, low-cost, and sustainable waste management strategies.

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Author Contribution

Zainab Hamed Salman conceived and designed the study, conducted the experiments, collected and analyzed the data, interpreted the results, and wrote the manuscript. The author is solely responsible for all aspects of the work, including literature review, data visualization, and preparation of figures and tables.

Conflict of Interest

The authors declared that no conflict of interest.

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